INCLUSIVE HADRONIC PRODUCTION OF THE B_c MESON VIA HEAVY QUARK FRAGMENTATION *

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ABSTRACT

We summarize the studies on the hadronic production of S- and P-wave $(\bar{b}c)$ mesons via direct fragmentation of the bottom antiquark as well as the Altarelli-Parisi induced gluon fragmentation.

The direct production of heavy mesons like J/ψ, Υ, and $(\bar{b}c)$ mesons can provide very interesting tests for perturbative QCD. According to the potential model calculation [1], for $(\bar{b}c)$ mesons the first two sets ($n=1$ and $n=2$) of S-wave states, the first ($n=1$) and probably the entire second set ($n=2$) of P-wave states, and the first set ($n=1$) of D-wave states lie below the BD flavor threshold. Since the annihilation channel of excited $(\bar{b}c)$ mesons is suppressed relative to the electromagnetic and hadronic transitions, the excited states below the BD threshold will cascade down into the ground state B_c via emission of photons and/or pions. Inclusive production of the B_c meson therefore includes the production of the $n=1$ and $n=2$ S-wave and P-wave states, and the $n=1$ D-wave states. Here we do not include the D-wave contributions since they are expected to be very small.

Intuitively, the dominant production of $(\bar{b}c)$ mesons at the large transverse momentum region should come from the direct fragmentation of the heavy $\bar{b}$ antiquark [2,3]. We calculate the hadronic production of S- and P-wave $(\bar{b}c)$ mesons using the fragmentation approach [4,5,6]. The fragmentation approach essentially involves the factorization of the whole production process into the production of a high energy parton (a $\bar{b}$ antiquark or a gluon) and the fragmentation of this parton into various $(\bar{b}c)$ states. The novel feature in our approach [2,3] is that the relevant fragmentation functions at the heavy quark mass scale can be calculated in perturbative QCD. Let H denotes any $(\bar{b}c)$ meson states. The differential cross section $d\sigma/dp_T$ versus the transverse momentum p_T of H is given by

$$\frac{d\sigma}{dp_T}(p\bar{p}\to H(p_T)X) = \sum_{ij}\int dx_1 dx_2 dz f_{i/p}(x_1,\mu) f_{j/\bar{p}}(x_2,\mu)\left[\frac{d\hat{\sigma}}{dp_T}(ij\to \bar{b}(p_T/z)X,\,\mu)\right.$$
$$\left.\times D_{\bar{b}\to H}(z,\mu) + \frac{d\hat{\sigma}}{dp_T}(ij\to g(p_T/z)X,\mu)\; D_{g\to H}(z,\mu)\right]\,. \quad (1)$$

For the production of $\bar{b}$ we include the subprocesses $gg\to b\bar{b}$, $g\bar{b}\to g\bar{b}$, and $q\bar{q}\to b\bar{b}$; while for the gluon g we include the subprocesses $gg\to gg$, $q\bar{q}\to gg$, and $gq(\bar{q})\to$

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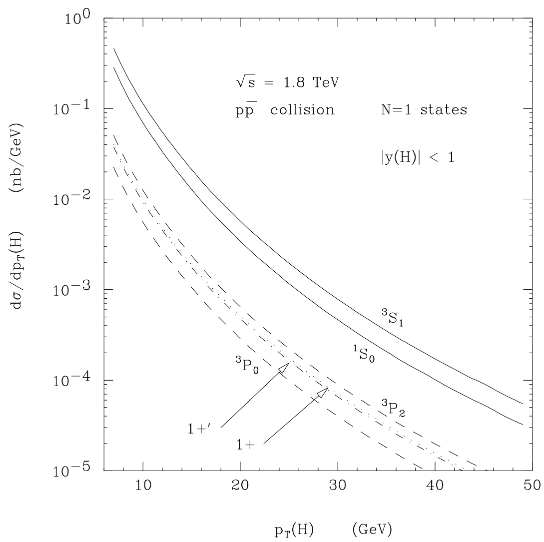

Figure 1: The differential cross section $d\sigma/p_T$ versus p_T of the $(\bar{b}c)$ meson (H) in various spin-orbital states with $n = 1$ at the Tevatron. The acceptance cuts are $p_T(H) > 6$ GeV and $|y(H)| < 1$.

$gq(\bar{q})$. In Eq. (1), a common scale μ is chosen for parton distribution functions, parton-parton scattering, and fragmentation functions. We estimate the dependence on μ by varying the scale $\mu = (0.5 - 2)\mu_R$, where $\mu_R = \sqrt{p_T^2(\text{parton}) + m_b^2}$. This choice of scale avoids the large logarithms in the short-distance part $\hat{\sigma}$'s. However, logarithms of order μ_R/m_b have to be summed in the fragmentation functions, which is implemented by evolving the Altarelli-Parisi (AP) equations for the fragmentation functions [4,5]. The initial conditions for the AP equations are the fragmentation functions that we can calculate by perturbative QCD at the initial scale μ_0, which is of the order of the b-quark mass. At present, all the S-wave [2] and P-wave [3] fragmentation functions for $\bar{b} \to (\bar{b}c)$ have been calculated to leading order in α_s. To obtain the fragmentation functions at an arbitrary scale greater than μ_0, we numerically integrate the AP evolution equations.

Other details in inputs can be found in Ref. 6. We impose $p_T(H) > 6$ GeV and $|y(H)| < 1$ cuts on the $(\bar{b}c)$ state H. The p_T spectra for the $(\bar{b}c)$ state H with various spin-orbital quantum numbers are shown in Fig. 1 and Fig. 2 for $n = 1$ and $n = 2$, respectively. Thus, we can also obtain the inclusive production rate of B_c as a function of $p_T^{\min}(B_c)$ by integrating the p_T spectra. Table 1 gives the inclusive cross sections for the B_c meson at the Tevatron as a function of $p_T^{\min}(B_c)$, including $n = 1$ and $n = 2$ S- and P-wave state contributions. The variations versus the scale μ between $\mu_R/2$ and $2\mu_R$ are always within a factor of two, and are rather insensitive to changes in scale when $p_T^{\min}(B_c) \gtrsim 10$ GeV.

At the end of Run Ib at the Tevatron, the total accumulated luminosities can be up to 100–150 pb^{-1} or more. With $p_T > 6$ GeV, there are about 5×10^5 B_c^+ mesons.

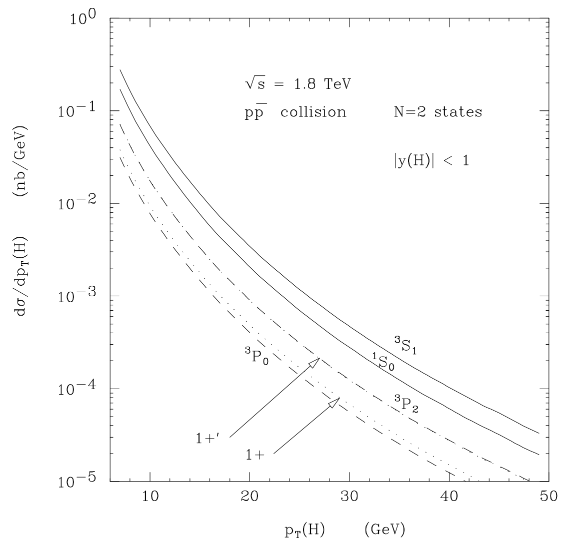

Figure 2: Same as Fig.1 for $n = 2$.

In the future, when the Main Injector is installed in the Run II, which can accumulate 1–2 fb^{-1} luminosity, there will be of order 10^7 B_c mesons. At the LHC there will be about 3×10^9 B_c mesons with $p_T > 10$ GeV at the assumed 100 fb^{-1} luminosity.

In conclusion, there should be enough signature events to confirm the existence of B_c at the Tevatron, and the LHC will be a copious source of B_c. This work was supported by US DOE-FG03-93ER40757.

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Table 1: Inclusive production cross sections for the B_c meson at the Tevatron including the contributions from all the S-wave and P-wave states below the BD threshold as a function of $p_T^{\min}(B_c)$. The acceptance cuts are $p_T(B_c) > 6$ GeV and $|y(B_c)| < 1$.

$p_T^{\min}$ (GeV)	σ (nb)		
	$\mu = \frac{1}{2}\mu_R$	$\mu = \mu_R$	$\mu = 2\mu_R$
6	2.81	5.43	6.93
10	0.87	1.16	1.22
15	0.26	0.29	0.26
20	0.098	0.097	0.083
30	0.021	0.018	0.014